Chapter 2
Bt Cotton in Burkina Faso Demonstrates That Political Will Is Key for Biotechnology to Benefit Commercial Agriculture in Africa

H. Traoré, S.A.O. Héma, and K. Traoré

Abstract In 2009, the first year of commercial production of Bt cotton in Burkina Faso, producers planted 129,000 ha, making this the largest introduction of biotechnology on the African continent. The plantation area doubled in 2010 (256,000 ha), but decreased in 2011 (251,580 ha). In 2012, the area of Bt cotton cultivated increased to 300,000 ha. The speeding-up of agricultural biotechnology development in the country is not only due to the political will of authorities, but also because of the determination of stakeholders including scientists, producers, and cotton companies in biotechnology adoption. Therefore, the country's experience provides an excellent example of the processes and procedures which must be gone through for a biotechnology product to be successfully introduced into a developing country where agriculture is a crucial contributor to the gross domestic product (GDP).

The Institute of Environment and Agricultural Research (INERA) and Monsanto conducted controlled experiments with insect-resistant Bt cotton from 2003 to 2006. Success obtained during this seed development program led to evaluating Bt cotton for insect-resistance on a larger scale by commercial farmers in 2007; Bt cotton was commercially released in 2008. Meanwhile, the national rules for safety in biotechnology were adopted in June 2004, and the National Biosafety Agency (NBA) established in 2005. The law on biosafety was passed by the Parliament on March 2006 and promulgated on April 2006. Neighboring countries, especially Benin, Chad, and Mali, would benefit from Burkina Faso's experience, being next in line to introduce Bt cotton.

Keywords Bt cotton • Bollgard II cotton • *Bacillus thuringiensis* • *Helicoverpa armigera* • Biotechnology • Burkina Faso • Cotton value chain

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Abbreviations

AAB	African Agency of Biotechnology
AATF	African Agricultural Technology Foundation
ABNE–NEPAD	African Biosafety Network of Expertise – New Partnership for Africa's Development
AIC-B	Inter-professional Cotton Association of Burkina
ANVAR	National Agency for the Valorization of Research Results (Burkina Faso)
ARC	Support to Research on Cotton
ATC	Cotton technical agent
BBA	Burkina Biotech Association
Bt	*Bacillus thuringiensis*
CBD	Convention on Biological Diversity
CC	Cotton correspondent
CCPs	Critical control points
CFDT	Company for the Development of Textile Fibers
CIRAD	International Center in Agricultural Research for Development
CIRDES	International Centre for Research and Development of the Livestock in Sub-humid Zones
CNRST	National Centre for Scientific and Technological Research (Burkina Faso)
CNSB	National Scientific Committee of Biosafety (Burkina Faso)
CORAF/WECARD	West and Central African Council for Agricultural Research and Development
CSIB	Internal Scientific Committee of Biosafety (Burkina Faso)
Dagris	Development of South Agro-Industries
ECOWAS	Economic Community Of West African States
FAO	Food and Agricultural Organization
FARA-SABIMA	Forum for Agricultural Research in Africa – Strengthening Capacity for Safe Biotechnology Management in Sub-Saharan Africa
GDP	Gross domestic product
GMO	Genetically modified organism
GPCs	Groups of cotton producers
IFPRI	International Food Policy Research Institute
INERA	Institut de l'Environnement et de Recherches Agricoles (Institute of Environment and Agricultural Research) (Burkina Faso)
INSD	L'Institut National de la Statistique et de la Démographie
IPS	Industrial Promotion Services
IRCT	Institute for Research on Cotton and exotic Textiles
ISAAA	International Service for the Acquisition of Agri-biotech Applications
LMOs	Living modified organisms

MAHRH	Ministère de l'Agriculture, des Ressources Hydrauliques et de la Pêche
NBA	National Biosafety Agency (Burkina Faso)
NBC	National Biosafety Committee (Burkina Faso)
ONB	National Observatory for Biosafety (Burkina Faso)
PPP	Public/private partnership
RECOAB	West African Network of Communicators in Biotechnology
SOP	Standard operating procedure
SSA	Sub-Saharan Africa
UD	Departmental union
UEMOA	West African Monetary and Economic Union
UNEP–GEF	United Nations Environment Program project–Global Environment Facility
UNPCB	National Union of Cotton Producers (Burkina Faso)

Political Will to Support the Use of Biotechnology

The speeding-up of agricultural biotechnology development in the country is not only the result of political will of authorities, but also the determination of stakeholders including scientists, producers, and cotton companies in biotechnology adoption. Burkina Faso's experience over the past decade provides an excellent example of the processes and procedures required for a biotechnology product to be successfully introduced in a developing country (Vitale et al. 2010); and nearly a decade of coordinated efforts by the various cotton stakeholders was necessary to satisfy a series of technical, legal, and business requirements.

Authorities were engaged at the highest level, as is evident when referring to the speech given by his Excellence Blaise Compaoré, President of Burkina Faso, at the opening ceremony of the Ministerial Conference on Harnessing Science and Technology to Increase Agricultural Productivity in Africa: West African Perspectives. This conference was held in Ouagadougou from June 21 to 24 in 2004, and this speech gives an idea about the political will of the country to encourage the use of biotechnology (Compaoré 2004).

The organization of this meeting was itself a manifestation of the political will of the authorities to move towards biotechnology, and President Compaoré stressed that the exploitation of science and technology to increase agricultural productivity in Africa is pertinent and up to date, for, while agricultural productivity is in increase worldwide, food insecurity still prevails in the African continent. Being the "cradle of humanity", Africa should not miss yet another revolution because, despite the progress made by humanity—thanks to the mastery by human beings of sciences and technology—it is today lagging behind in indispensable discoveries that can ensure the development and well-being of its populations. The Food and Agricultural Organization (FAO) experts' initiative in favor of the use of biotechnologies in the agricultural field to increase productivity and reduce hunger all over the world was relevant. Additionally, the biotechnological revolution should not only be at the origin of recorded progress in the agricultural sector, but also in other domains such as the management of natural resources, health, and industry (Compaoré 2004). The contribution of biotechnology is very important in meeting the future needs of the growing populations in developing countries, particularly in Africa, whose population of 1.1 billion is expected to quadruple by 2,100 to reach 4.2 billion (UN Population Division). To satisfy these population needs and achieve this challenge, the African continent needs to acquire and adapt biotechnologies to the agricultural sector, to increase its current production from 10 to 12 times, and strengthen the collaboration between Burkina Faso's researchers and Monsanto in the experimentation of transgenic cotton (Compaoré 2004). The President also expressed his support for the creation of an African center for research, information, and training in biotechnology, that will strengthen a cooperative relationship between African institutes and institutes in the rest of the world, to give a motivating career to researchers, and attract high-level senior personnel who invest themselves in scientific and technological research.

On June 23, 2004, in his remarks at the same ministerial conference, Dr. J.B. Penn, Under Secretary, Farm and Foreign Agricultural Services U.S. Department of Agriculture, reported an exchange with a journalist: "On the first day of this conference, a journalist here asked me, what is the best thing that this conference can bring to Africa? I answered in one word: Knowledge" (Penn 2004).

For the Secretary, the problem is not the availability of technology in the world that can make a significant positive difference in people's lives here in West Africa, but getting that technology to the people and helping them make use of it—adapting it as necessary and making it easily accessible (Penn 2004). Therefore, this conference provided the opportunity for everyone to share information on technologies, policies, and partnerships, to increase agricultural productivity in West Africa. With regard to biotechnology, Dr. Penn stressed that it is not the American goal to force any technology on anyone. However, there are very positive signs of growing acceptance around the world with regard to products of modern biotechnology and the benefits that they offer. Also, to him, a conference like this, here in West Africa, is a reminder that although friends like the United States may play a helpful role, Africa holds the key to its own development.

The strategic plan for agricultural research in Burkina Faso developed in 1995 [National Centre for Scientific and Technological Research (CNRST) 1995], was carried out in a particular context to boost cotton production. Research programs developed from the demand of producers and existing markets were implemented by combining the most relevant operators. The objectives assigned to the research focused on crop intensification, and improving the profitability of the sector, while ensuring the preservation of natural resources. Thus, since that period, modern biotechnology, including genetically modified (GM) crops, has been identified as a solution to the challenges faced by the cotton sector.

From Experimentation to Commercialization of Bt Cotton in Burkina Faso

INERA in Burkina Faso, as well as the National Agency for the Valorization of Research Results (ANVAR) of the National Centre for Scientific and Technological Research (CNRST), played an important role in the adoption of the Bt cotton technology in Burkina Faso (Zangré 2009; Vitale et al. 2010).

One reason which can explain the interest of Burkina Faso in GMOs is that cotton, the main cash crop of the country was strongly attacked in the 1990s by pests, mainly *Lepidoptera* (*Helicoverpa armigera*), which become resistant to insecticides. An important step was also the encounter with Bollgard technology from Monsanto, at the 1999 workshop at Yaoundé. So, ANVAR and the Cotton Program of INERA invited Monsanto to visit Burkina Faso, to present this technology at a meeting of policy makers and people who are interested in cotton in Burkina Faso (Zangré 2009).

From 2000 to 2001, several national workshops for sensitization and awareness creation were organized in Ouagadougou on Monsanto's Bt technology, targeting the key players in cotton (researchers, teachers, ministries, cotton growers, cotton companies, and civil society). Thus, the first major official meeting on Bt cotton was organized in 2000 in Burkina Faso, under the auspices of the CNRST. The workshop was also attended by the concerned ministries (higher education and scientific research, agriculture, animal resources, environment, foreign affairs, finance), civil society, researchers [CNRST, University of Ouagadougou, International Centre for Research and Development of the Livestock in Sub-humid Zones (CIRDES)] Sofitex, the National Union of Cotton Producers of Burkina Faso (UNPCB), and resource persons. This was an opportunity for Monsanto to introduce the new Bt cotton technology that has since been much appreciated by participants, primarily representatives of cotton producers.

Cotton farmers required the acquisition of this new technology and experimentation on it by national researchers in Burkina Faso. However, insofar as Burkina Faso was party to the Convention on Biological Diversity and was about to sign the Cartagena Protocol, the workshop stressed the need for the country to first establish a national biosafety framework as a prerequisite before any importation of GMOs. Monsanto has welcomed this approach, and stated that its strategy is to work only in countries that have regulations on biosafety.

So, when the national rules on biosafety were almost ready, the authorities in Burkina Faso allowed INERA to experiment within the strict rules of confinement, with the Bt cotton of Monsanto known as Bollgard II and Vip of Syngenta, in 2003. Environmental assessments were conducted as part of the input biosafety protocols, along with monitoring the socio-economic impacts of the Bt technology (Vitale et al. 2010). From 2003 to 2005, INERA conducted 3 years of confined field trials (CFTs) to evaluate the biological efficacy of the Bt cotton on the populations of bollworms and particularly those of *Helicoverpa armigera*, and the environmental and health risk within the climate condition specific to Burkina Faso (Vitale et al. 2008, 2010; Traoré et al. 2008; Héma et al. 2009b). For the first 3 years, experiments were carried out with four American varieties (Coker 312 without the Bt gene, Coker 312 with the Bt gene, DP50 without the Bt gene, and DP50 with the Bt gene) at the research stations of Farako-Bâ near Bobo-Dioulasso in western Burkina Faso, and Kouaré, located in eastern Burkina Faso near Fada N'Gourma. The Biosafety Committee, in 2006, approved an additional CFT outside of the INERA research stations, and a series of backcrosses showed a successful transfer of the Bt gene from the American varieties to the three improved Burkinabé cotton varieties of INERA (FK 37, FK 290, STAM 59 A).

In 2006, for the fourth year of experimentation, Saria research station in the central zone, and Boni, a seed farm located 120 km from Bobo-Dioulasso on the axis of Bobo-Dioulasso-Ouaga, also hosted trials, in addition to the two research stations mentioned above. All the experimentation sites are located between the isohyets 800 mm and 1,000 mm.

The results of the bioassay obtained from 2003 to 2006 showed that the presence of the Bt gene in the American varieties and landraces helped to significantly reduce infestations of *Helicoverpa armigera*, *Diparopsis watersi*, and *Earias* spp. at Farako-Bâ, Kouaré, and Saria (Institute of Environment and Agricultural Research (INERA) 2007; Vitale et al. 2008, 2010; Traoré et al. 2008; Héma et al. 2009b). For the control of defoliator populations of *Syllepte derogata*, *Spodoptera littoralis*, and *Anomis flava* on the three sites, the efficacy of the Bt gene was equivalent to that of the standard pest control regimen of six sprays, and the cotton containing the Bt gene had no effect on the group of piercing and sucking Insects. A complementary program based on the last two insecticide treatments applied against the piercing-sucking pests of Bt cotton was as effective as the conventional six treatments.

With regard to economical evaluation, Bt cotton saves the first four treatments, which reduces the cost of insecticide protection of cotton by 67 % (INERA 2007). Bollgard II cotton provided a significant yield advantage of 14.7 % over conventional cotton, and the Bollgard II cotton had a significantly higher profitability than conventional cotton (Vitale et al. 2008, 2010; Traoré et al. 2008). The average profit obtained was 33,000 French CFA/ha compared to the insecticide protection program of the producers (six insecticide treatments per hectare).

A study was carried out on the impact of Bt cotton on the environment, auxiliary fauna, gene flow, and the effect of toxins produced by Bt cotton on populations of honey bees (INERA 2007). It reveals that the auxiliary fauna is not influenced by the presence of Bt cotton, and at 15 m, one cannot find more than 0.5 % of pollen from transgenic cotton.

With regard to the activity of honey bees, no significant abnormality or disturbance was noted in the behavior and the pace of development of bee colonies on Bt cotton plots, compared with the bees of conventional cotton fields (INERA 2007). On the contrary, a positive trend seems to be emerging for the mitigation of aggression of colonies, and for the increase in amount of honey stored, and speed of beam-capping. The comparison of lipid content between samples of cotton varieties DP50 and Bollgard II shows that there was no significant difference, but in contrast, the two varieties (DP50 and Bollgard II) have significantly different levels of protein. The study of the acute toxicity of endotoxin in rats reveals that the samples were of low toxicity: LD50 limit oral $>$ 3,000 mg/kg.

A key stage during this seed development program was the transition from conducting highly controlled research trials to evaluating Bt cotton for insect-resistance on a larger scale by commercial farmers (Traoré and Héma 2011). All agronomic advancements conducted by INERA need pre-extension testing before release, to verify real benefits for commercial farmers. In 2007, after the Bt cotton had successfully completed CFTs at research stations, 20 farmers (10 in the Sofitex zone, 6 in Socoma zone and 4 in Faso Cotton zone) from across Burkina Faso, enrolled in pre-extension tests in CFT conditions, for demonstration to farmers. An average yield increase of 20 % was obtained in 2007, and the NBA in June 2008 authorized the commercial planting of Bt cotton in Burkina Faso (Vitale et al. 2010), marking the first commercial use of Bt cotton in the country, and the third commercial release of a bioengineered crop in Africa. So, in the 2008 cotton-growing season, Sofitex and its contract seed producers planted 15,000 ha of the two local varieties containing the Bt gene to produce seeds for the next year. The way was then paved for the 2009 commercial planting of 125,000 ha of Bt cotton in Burkina Faso, the most extensive single-year biotechnology launch in Sub-Saharan Africa (SSA) to date (Vitale et al. 2010).

Bt cotton was commercialized in 2009, and a license agreement for 3 years renewable for production and distribution of Bollgard II seeds was signed between Sofitex and Monsanto. A collaborative 2-year agreement renewable for accompanying Bollgard II technology was signed between Monsanto and INERA, covering various areas (production of breeder seeds, defining technical itineraries adapted to the cultivation of Bollgard II, defining technical itineraries suited to the production of Bollgard II seeds, monitoring the efficacy of Bollgard II in field conditions, monitoring pests susceptibility to Bt toxins, monitoring non-targeted organisms by toxins, setting suitable refuge zones, and training and information of advice-support staffs and producers).

Evolution of Bt Cotton Hectarage, Seed Supply System, and Cohabitation with Other Cotton Crops

Evolution of Bt Cotton Hectarage

After successfully testing Bt cotton varieties in research stations from 2003 to 2006, in 2007 the demonstration phase of Bt cotton throughout the country, with 20 farmers considered as leaders, was an occasion to organize field days to familiarize producers with this new technology (Traoré and Héma 2011). Farmers were very enthusiastic about this experience; therefore, in 2008, the seed production of two transgenic local varieties was conducted on 8,500 ha. After various tests, chemical processing and packaging, the seeds produced in 2008 were used in 2009 to sow 129,000 ha, or 31 % of the total area under cotton (Table 2.1), of what was the first commercial production (Sofitex 2012). In 2010, the total area under cotton had decreased, but the area under Bt cotton doubled from 129,000 ha in 2009 to 256,000 ha in 2010; that is, 66 % of the total area. In 2011, Burkina Faso experienced an unprecedented crisis during the period of implementation of crops, despite the improvement seen in the global market of the fiber. Some farmer organizations were claiming lower sale prices for inputs and higher purchase prices of seed cotton. Therefore, they refused to sow and attacked those who did not respect their boycott. This situation, which was settled thereafter, had a negative impact on the distribution of Bt cotton seed. Thus, despite the increase in the total area of cotton, there was a slight decrease of about 5,000 ha in the area of cultivation of transgenic cotton. The amount of seeds produced in 2011 was not enough to satisfy all requests for the year 2012, as a result of which Burkina Faso's cotton growers planted 300,000 ha of Bt cotton, which represents 57 % of the total area under cotton.

Seeds Supply System

The seeds supply system developed in the context of conventional cotton production is the same for the production of transgenic Bt cotton (Sofitex 2012). Indeed, INERA annually produces at least 500 kg of breeder seeds that are available to Sofitex for producing foundation seeds at the Boni seed farm. The foundation seeds are then given to seed producers recognized for their compliance with technical innovations and recommendations for cotton production. They receive an additional premium for compliance with all the good agricultural practices applied to the seed. Seed producers then produce seed cotton which will provide certified seeds after a series of tests for the presence of genes of interest and consistent germination. Seed treatment and packaging are done by Sofitex, which supplies all producers according to their specific needs.

Cohabitation of Bt Cotton with Other Cotton Crops

It is also interesting to see the cohabitation of the three types of cotton crops. In Burkina Faso, three types of cotton co-exist in the same ecosystems: conventional cotton, consisting of conventional local varieties, which uses conventional inputs such as mineral fertilizers and pesticides (herbicides, insecticides, fungicides); the transgenic Bt cotton, which consists of landraces back-crossed with the Cry gene from *Bacillus thuringiensis*, and also uses conventional inputs such as mineral fertilizers and pesticides; and organic cotton made of conventional varieties,

Table 2.1 Evolution of the Bt cotton area from 2009 to 2012

Year	Total area under cotton (hectares)	Area under Bt cotton (hectares)	Rate of Bt (% of total)
2009	420,000	129,000	31
2010	386,000	256,000	66
2011	429,000	251,580	59
2012	530,000	300,000	57

which does not use any synthetic chemicals without the label "organic". This type of cotton is quite minimal (less than 1 % of the total area of cotton in Burkina Faso), and uses organic fertilizers and organic pesticides. It is mainly grown by women's groups which do not have access to enough input credit for the production of the other two types of cotton. Cotton producers are free to choose the type of cotton they wish to grow. Only in the case where Bt cotton is chosen, it is necessary to install approximately 20 % of conventional cotton, treated according to the conventional standard program recommended, that is six insecticide treatments starting 30 days after emergence, with an interval of 15 days between treatments. This measure, called 'refuge area', allows the dilution of resistance genes to Bt toxins, ensuring the sustainability of the technology. An isolation distance between the different types of cotton grown is respected to avoid pollution. Also, crops are separated and transported separately to the ginneries. Cohabitation between cotton crops generates costs that producers want to minimize, and their establishment near to each other is avoided. Research is underway in INERA to determine crops and their percentages in terms of areas to even replace conventional cotton for the sustainability of Bt technology.

Legislative Framework Implementation by the Bodies in Charge of Biosafety Law

Burkina Faso has been part of many international commitments, and participated in their implementation. In 1992 in Algiers, Burkina Faso co-founded with 15 other member states the African Agency of Biotechnology (AAB). The AAB works to strengthen the capacity of member countries in biotechnology and for the promotion of commercial biotechnology. Ever since, the country has manifested its intention to promote the development of biotechnology (Zangré 2009).

The Cartagena Protocol on Biosafety was derived from the Convention on Biological Diversity (CBD) adopted in May 1992 in Nairobi (Kenya), and Burkina Faso signed the CBD in 1993.

In the application of the precautionary principle on environment, as stated in the Rio Declaration of 1992, the establishment of an international instrument in the form of a protocol, which was inclusive of permission to manage biosafety issues, including the cross-border movements of GMOs, became imperative.

Thus, in 1995, the Convention designated a group of 15 experts, respecting regional balances, to address the issue. Burkina Faso and South Africa represented South Saharan Africa in Cairo (Egypt) in the consultation that recognized the novelty of living modified organisms (LMOs) (later called GMOs), and recognized the need to negotiate an international protocol to manage biosafety issues that would come from biotechnology. The country has participated in the consultation of the United Nation Program for Environment, with regard to the adoption of transitional guidance, pending after the Protocol. From 1996 to 2000, from Aarhus (Denmark) to Montréal (Canada), Burkina Faso has contributed to the non-limited group in terms of composition, on the Cartagena Protocol. The country was also part of the 2001 panel of experts for the development of the Model Law on Safety in Biotechnology of the African Union.

Burkina Faso has participated from the beginning to the end of this long negotiation process involving several meetings, through the CNRST, the Ministry of Environment and Life Framework. The negotiations led to the adoption of a binding protocol in 2000 in Nairobi, which came into force on September 11, 2003. The Government of Burkina Faso ratified the Cartagena Protocol on August 04, 2003. In the application of the Protocol, the signatory countries undertook to implement national biosafety frameworks whose scope was not below the protocol. In 2004, Burkina Faso ratified the legal instruments of the AAB, and recently adopted, in 2010, the Supplementary Protocol on Liability and Redress, known as the Nagoya–Kuala Lumpur Protocol.

A workshop held on March 2000 set up a temporary committee chaired by ANVAR, CNRST, and was composed of one representative from the Ministry of Environment and Life Framework, University of Ouagadougou, INERA, and a representative of civil society as a resource person, to think and develop a national biosafety framework. This committee worked for 2 years, until 2002, to provide a document entitled "National rules on safety in biotechnology", which was enriched by the recommendations of the United Nations Environment Program project–Global Environment Facility (UNEP–GEF), carried out by the Ministry of Environment and Life Framework for the implementation of the national biosafety framework. Subsequently, the rules were validated by a national workshop held in Ouagadougou in November 2003.

A National Framework on Biosafety, the result of extensive national consultations with stakeholders and all categories of users of GMOs and derived products (ministries, civil society organizations, NGOs, traders) was created in 2003.

The adoption of National Rules for Safety in Biotechnology on June 18, 2004 by decree by the Government of Burkina Faso represents a significant step forward in the regulation of GMOs in the country. A National Biosafety Committee (NBC) was implemented in 2004. Inspired by national rules, a law on security in Biotechnology in Burkina Faso was passed by the National Assembly in March 17, 2006 and promulgated on April 13, 2006 with eight titles and 75 articles. The biosafety law has been translated into three local languages. The implementation of the NBC is done through different regulation bodies: National Biosafety Agency (NBA)—created in 2005, National Scientific Committee of Biosafety (CNSB), National

Observatory for Biosafety (ONB), and Internal Scientific Committee of Biosafety (CSIB).

Overview of the Agriculture and Cotton Sector in Burkina Faso

History of Cotton Production in Burkina Faso: Independence to the Present

Burkina Faso is a landlocked West African country with an area of 274,000 km^2 (of which 9 million hectares is arable land), a population estimated in 2006 at 14,017,262, and an annual growth rate of 3.1 % [L'Institut National de la Statistique et de la Démographie (INSD) 2008]. The rural sector is important in the national economy, since 86 % of people are farmers. Agriculture contributes 40 % to the GDP, with 25 % for crop production, 12 % for livestock, and 3 % for forestry and fishery (Ministère de l'Agriculture, des Ressources Hydrauliques et de la Pêche [MAHRH] 2008). Agriculture contributes to 44.7 % of total household income, with 24.3 % from crop production and 20.4 % from livestock. Cotton is the principal cash crop in Burkina Faso, generating over US $300 million in annual revenues. It accounts for between 5 % and 10 % of the GDP in Burkina Faso (International Food Policy Research Institute [IFPRI] 2006), and represents more than 50 % of the country's export earnings (INERA 2002).

Cotton has been grown for more than a century in the Sahelian and Sudanian savannas of West Africa (Club du Sahel 2005). Cotton has played an important role in the economic development of many countries in West Africa, and it still remains an important source of income for many of them. Grown for its fiber and the oil extracted from the seed, cotton is the main export crop in many West African countries. In West Africa, cotton cropping is the main economic activity for more than 1 million households, and sustains some 10 million farmers. The bulk of the production is carried out by small farmers producing their cotton under rain-fed conditions on areas of 1–2 ha and generally practicing cotton–cereal rotation. Traoré et al. (2008) report that cotton has been the primary catalyst to economic development because where it is grown, rural infrastructural growth has been seen. Therefore, cotton has been the driving force behind the construction of roads, schools, banks, and hospitals in rural areas. Africa has hundreds of varieties of cotton, some of which date back to the tenth and thirteenth centuries. Grown in rain-fed conditions on about 2.4 million hectares, cotton production in West Francophone Africa has been for nearly 40 years the main engine of economic growth (Chetaille 2006). With a production of 730,000 t of seed cotton in 2005, Burkina Faso is now the first cotton producer in Africa, and the development of this crop has been a success, which has helped to reduce poverty in areas where it is practiced.

The Withdrawal of Government, and the Organization of the Value Chain

Cotton production on a large scale began in the 1950s with the French Company for the Development of Textile Fibers (CFDT), now called Development of South Agro-Industries (Dagris), which introduced new cotton varieties (American Upland cotton) for the purpose of the textile industry. The association of Upper Volta-CFDT was created, and lasted from 1970 to 1979. On June 20, 1979, the Government of Upper Volta created the Society of Textile Fibers, which in 1984, became Sofitex, the Burkinabè Company of Textile Fibers. Dagris performed nearly all activities including production of seed cotton and stabilization of prices and incomes, with the exception of agricultural research. From the "one-stop" cotton farming system in which Sofitex provided all the production inputs and also purchased all the seed cotton from the farmers, the Government of Burkina Faso divested itself in 2002 of complete control of the cotton sector (Traoré et al. 2008). In late 2004, Sofitex sold the production area of the Centre to the consortium of Industrial Promotion Services (IPS) and Paul Reinhart AG, and the East Zone to Dagris; Sofitex has, meanwhile, maintained its role in the West Zone. It should be noted that the institutional aspect, however, has played a major role in the geographical distribution of seed cotton production. Cotton production always begins in areas where the government guaranteed to producers, through the intermediary semi-public cotton company, the purchase of any seed cotton produced, and thus created some income security appreciated by producers.

Organization of Cotton Production

Production Cycle

The production of seed cotton involves producers, the extension services of cotton companies, and agricultural research. The success of this production requires the organization of the value chain and the various actors (cotton companies, producers, cotton research, carriers, and so on) for the supply of inputs, and marketing. Apart from cotton seed, other inputs such as fertilizers, cotton insecticides, herbicides, and treatment devices are subject to import through international tenders.

The breeder seeds are produced by the cotton research program of INERA and multiplied into foundation seeds at the farm-level by cotton companies (Sofitex). Certified seed production is provided by individual producers in informal contracts with the cotton companies. The establishment of seeds and insecticides takes into account soil and climatic conditions, and the parasitic infestation level of each production area. Producers play an important role in the production cycle. Cotton is grown in a strictly rain-fed regime by smallholders practicing mainly animal traction. Over 90 % of farms have less than 5 ha, and the average area covered by the cotton is between 1 ha and 2.5 ha per farm. One can easily distinguish between collective cotton farms and individual cotton farms. Collective farms include individual producers organized into groups of cotton producers (GPC), with each group containing 15–40 or more farmers. Individual farm producers are not members of GPCs. There are approximately 325,000 cotton farmers [National Union of Cotton Producers Institute of Environment and Agricultural Research INERA (2007)] in Burkina Faso.

The Institute of Environment and Agricultural Research INERA is a group of farmers from the village to the province (Traoré 2007). According to Mr. François B. Traoré, former President of UNPCB, "the group began in 1996 and in 1998 we established the office of the National Union". In 1999, the producers became a shareholder in Sofitex, the national cotton company, and in 2005 they became shareholders in the new companies that were put in place after the privatization. So the cotton sector is jointly owned by the Burkina Faso Government, the private sector, producers, and three companies that are operating in three different zones, each maintaining the "one-stop" cotton farming system (Traoré et al. 2008). The production of Burkina Faso was around 116,000 t of seed cotton in 1996, but in 2005–2006 production in the country reached 713,000 t. Thus, Burkina Faso became the first African country to be a producer of cotton. The cotton price is negotiated among the principal stakeholders, giving producers a significant voice in determining cotton price levels, and that has created a climate of trust between the producers and the companies, which is very important in terms of trade.

The research also plays an important role in the sector. The CFDT was created in 1949, began its activities in Upper Volta in 1951, and then benefited from the collaboration of the French Institute for Research on Cotton and exotic Textiles (IRCT) of the International Center in Agricultural Research for Development (CIRAD), established in 1946. The objectives of CIRAD were to study and breed for high-yielding varieties adapted to different regions. Cotton research in Burkina Faso was led mainly by the IRCT until the year 1985.

The cotton research is actually implemented by the cotton program of INERA, which reports to the Crop Production Department, whose mission is to develop cotton varieties with good productivity in the field, and with technological characteristics that meet the requirements of international market. This program is under the responsibility of a Program Manager, supported by section leaders. Major research activities are conducted in these four sections: varietal improvement, agronomy and cultural techniques, crop-protection, and agro-socio-economics.

There is a mechanism of programming, implementation, and dissemination of research findings. Programming research activities is done for a period of 3 years. These activities are part of the strategic plan of the national research, and take into account the concerns of the sector.

In 1988, Sofitex and INERA signed an agreement entitled "Support to Cotton Research [Agricultural Research Corporation (ARC)]". With the signing of the contract plan between Sofitex and the Government in 1993, a new way of funding cotton research has been proposed on the basis of 1.5 F CFA/kg[1] of fiber produced. Although this ratio has never been reached, the cotton research has consistently received funding from the cotton sector.

The privatization of the cotton sector in 2004 has not fundamentally changed this mechanism of funding research. The Inter-professional Cotton Association of Burkina (AIC-B), which includes the three cotton companies (Sofitex, Socoma, and Faso Cotton), and the UNPCB decided to finance cotton research that presents its results each year and submits its work plan and budget to the Management Committee of the AIC-B, which in turn conducts an appraisal.

Research activities on cotton are funded by the value chain through the Protocol "Support to Cotton Research (ARC)" signed between the management committees of AIC-B and INERA, and their activities take into account cotton-based production systems.

Evolution of the Extension System

Extension has been provided since 1992, primarily by cotton companies that have services in the field. The current system consists of approximately 120 cotton correspondents (CC) and 300 cotton technical agents (ATC). There is about one CC by departmental union (UD) and one ATC for about 50 groups of cotton producers. Programming the extension activities is done annually and it covers the technical itinerary and the use of new technologies. Extension is more concentrated on cotton. The Ministry of Agriculture provides some extension services through an advice–support to producers for all farm activities and on issues not specific to cotton. The extension system ensures a continuous advice–support. This form of extension seems only mildly effective for certain categories of producers, given the level of professionalization of some of them. Thus, the agricultural farming council is an alternative for a more appropriate extension.

Major Achievements in Cotton Research

Among the main achievements, one can notice the presence of a gene bank of over 200 varieties (with gland or glandless), and ten varieties of colored fibers created at the Farako-Bâ research station (INERA 2007). These colored varieties are not cultivated, but were created to anticipate the demand of the international market.

In collaboration with Monsanto, three caterpillar-resistant varieties were newly created, and their experimentation is ongoing.

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[1] F CFA states for: Franc of the African Financial Community, a currency in 8 West Africa francophone countries (Benin, Burkina Faso, Côte d'Ivoire, Guinea Bissau, Mali, Niger, Sénégal, Togo).

Three cotton varieties are grown in Burkina Faso: two Burkinabè varieties (FK290 and FK37) are grown in areas where annual rainfall exceeds 800 mm, and a Togolese origin variety (STAM 59A) is grown in areas of low annual rainfall (INERA 2007).

Research in agronomy has led to the optimization of mineral fertilizer formulas in cotton cultivation. Problems related to the fertilization of cotton are studied to propose formulas for mineral fertilizers and organic manures in suitable farming systems based on cotton and cereals. This work has led to propose "bulk blending" of cotton fertilizer, which has a similar efficacy to that of complex fertilizer which was previously used exclusively.

Competition from weeds due to delays in weeding resulted in yield losses of about 200 kg/ha of seed cotton per decade, along with an impairment of cotton quality (INERA 2007). More than 20 new herbicide formulations were popularized, and the use of herbicides for 3–4 consecutive years results in reduction in weeding time from 20 h/ha to 40 h/ha on plots with medium to high weed infestation, and a yield improvement of more than 11 %.

The main achievements in entomology take into account good knowledge of periods and durations of proliferation of population of the main insect pest species (INERA 2007). For bollworms, the period of abundance of species is during the first 3 weeks for *Diparopsis*, and the last 5 weeks for the *Helicoverpa* and *Earias*, while for the defoliators, the period of abundance is the entire cotton cycle. With regard to piercing and sucking insects, aphids and whiteflies are present throughout the cycle, with a remarkable abundance at the beginning and end of the cycle for the first, and end of cycle for the latter.

Studies undertaken on the social and economic importance of cotton showed that cotton represents 61–65 % of the income of producers, but only 31 % of this income is reinvested in agricultural activities (INERA 2007). The rest is divided between real estate and luxury, social spending, and general purchases. Cotton is also a relay to the development of traditional cereals. Studies have shown that income management is a key factor to ensure the sustainability of the farm. This requires the development of a suitable farm council, which will enhance the ability of the producer to make the diagnosis of its farm in order to consider actions to improve incomes. The impact studies undertaken have shown that investment in agricultural research have been very profitable. For an investment of 10.19 billion CFA francs over 20 years (1980–2000) in research and extension on cotton, profits generated for producers and consumers are estimated at 59.606 billion F CFA. Therefore, investment in cotton research and extension is a viable use of public funds and development assistance.

Constraints to Cotton Production and Challenges

Despite the great contribution of cotton (conventional cotton for many years and recently the Bt) to the agricultural sector of Burkina Faso, the country is beset by a number of challenges that undermine production, including vulnerability to climate shocks, low yields due to the extensive nature of farming practices, drought, poor soil, weeds, the low level of technology transfer, the difficulties faced by producers to access new technologies, and lack of infrastructure and inadequate credit.

In addition, the cotton plant faces serious damage by many pests, particularly insects feeding upon the leaves and fruits, and yield losses on most cultivated varieties may represent 90 % of potential yields in conditions where no control measures against pests and diseases are undertaken (Michel et al. 2000). In Burkina Faso, most damage is due to two principal groups of caterpillar (*Lepidoptera*) pests which can be distinguished by their feeding preferences: (1) bollworms or fruit-feeders, the most prevalent of which are *Helicoverpa armigera* (*Hübner*) (old world bollworm), *Diparopsis* spp. (red bollworms), and *Earias* spp. (spiny bollworms), and (2) defoliators, which are primarily *Syllepte derogata* (*Fabricius*) (cotton leafroller), *Anomis flava* (*Fabricius*) (looper), and *Spodoptera littoralis* (*Boisduval*) (cotton leafworm) (Héma 2004).

From 1980 to 1995, cotton in the West African sub-region including Burkina Faso was protected from caterpillar damage by the application of binary insecticides containing both pyrethroids and organophosphates, often associated in the same treatment (Martin et al. 2000; Héma 2004). But since 1995, applications of insecticides have failed to control insects, particularly the larvae of *H. armigera*, confirming the presence of resistance (Martin et al. 2000; Héma 2004) and leading to an increase in the number of insecticide applications (from 6 to 8) by cotton growers, to reduce pest infestation. The consequences were higher production costs and adverse effects on human health and environment. Vitale et al. (2006) reported that, in a typical year, the Burkina Faso cotton sector uses over US $60 million of chemical-based pest control products. Despite that, a recently conducted study in Burkina Faso found significant pest damage on fields that were protected using a standard regimen of six seasonal sprays. Thus, the introduction of GM cotton plants expressing the Cry1Ac and Cry2Ab toxins (Perlak et al. 2001; Greenplate et al. 2003; Héma et al. 2009a), which have a different mode of action as opposed to that of pyrethroids, became an interesting and effective alternative to chemical control. Different studies have shown in other areas of the world that transgenic cotton or transgenic maize use has greatly reduced pesticide treatment, while effectively controlling insect pests [Pray et al. 2002; International Service for the Acquisition of Agri-biotech Applications (ISAAA) 2010]. So, to reduce losses due to pest damage, authorities and stakeholders in the cotton sector including scientists, producers, and cotton companies of Burkina Faso decided to evaluate the Bt technology. The results from the evaluation led to the adoption of Bt cotton.

The Way Forward: Lessons Learned from Burkina Faso's Experience

With regard to biotech crops, today the African continent represents by far the biggest challenge in terms of adoption and acceptance (James 2010), and the decision in 2008 by Burkina Faso to grow 8,500 ha of Bt cotton for seed multiplication and initial commercialization (Vitale et al. 2008, 2010; Traoré et al. 2008; Traoré and Héma 2011), and for Egypt to commercialize 700 ha of Bt yellow maize hybrid for the first time (Sawahel 2008; ISAAA 2007, 2010; ABNE 2010) was of strategic importance for the African continent. Burkina Faso and Egypt took the leadership in West Africa and North Africa respectively, in addition to South Africa for Southern and Eastern Africa, for commercializing biotech crops in 2008. This broad geographical coverage in Africa is of strategic importance in that it allows the three countries to become role models in their respective regions, and allows more African farmers to become practitioners of biotech crops and to be able to benefit directly from "learning by doing", which has proven to be such an important feature in the success of Bt cotton in China and India (James 2010).

In Egypt, during a field visit organized by the Egypt Biotechnology Information Center which witnessed a gathering of 50 scientists, maize breeders, and private company representatives, as well as 100 farmers in Bt maize fields in the Sharkia Delta, Egypt last August 23, 2010 (ISAAA 2010), Prof. Magdy Massoud from the Alexandria University explained to the audience that the Bt maize variety could be planted at any time of the season, as it is resistant to the maize borer. He also added that the new variety increases corn yield by up to 30 %. In response, farmers had expressed their interest in the variety, noting that they could use less pesticide and labor, and have higher yields in addition to the benefit of it being an environmentally friendly crop. Moreover, after intensive Bt maize field trial studies in over 36 maize-growing areas in Egypt, Dr. Magdy Abdel Zaher pointed out that "The use of biotech maize saves on pesticide usage, gives almost 100 % protection from stem borers and increases yield by 30–40 % over the conventional maize varieties" (Abdallah 2010). The future of biotechnology seemed brighter for the benefit of farmers not only in the context of Bt maize, but also for potato, cucurbits, wheat, rice, and tomato, which are in the pipeline (Abdallah 2010).

In Burkina Faso, to know how the Bt cotton technology adoption complied with producers' will, their point of view must also be understood. In response to the question "Could transgenic cotton be a solution?" Mr François B. Traoré, former UNPCB President, in 2007 replied, "Yes, Bt cotton can be one of the solutions. You know the Bt cotton was developed by researchers who are at the same time traders. Their goal is to reduce the use of pesticides for the treatment of parasites in our fields. This research is accompanied by action plans that will allow these companies to make a profit. Meanwhile, manufacturers and sellers of pesticides that are reducing their future earnings cannot be happy. The second aspect is the novelty. All that is new is scary and raises questions. There are people that evoke our dependence vis-à-vis those firms producing Bt cotton seeds. But listen, it's trade, both parties must benefit from this trade. If this is not the case, we'll see. We are not associated with these companies for eternity. If we do not take advantage of this trade, we will stop. There are also people who evoke our dependence vis-à-vis these firms with regard to seed production. Do you think today that the producer who uses the seeds he obtained from his grandfather may have good yields? This simply means that the improvement of cotton seeds by GMOs can be a way out for us. This will eliminate the cost benefits associated with pesticides, reduce diseases related to the use of these pesticides, we save time and many other things. The issue of dependency is not real. I'm just saying that money does change hands. It is the pesticides seller who will lose, to the benefit of the Bt cotton seeds seller. Realistically, there are people who wonder if you can eat GMO food. The American are richer than us, the Chinese are richer than we, Hindus are richer than us and yet GMOs are cultivated and consumed. So why do we think it will lead to death? In view of all these aspects, I think we have nothing to lose by adopting GMOs. Rather, it can improve our outcome".

Nevertheless, the Egyptian experience was unfortunately stopped in 2010 because of the non-promulgation of any law, even though a drafted national biosafety law has existed since 2004 (Sarant 2012), revealing the complexity of processes and procedures necessary to support the adoption of an agricultural biotechnology product.

Innumerable lessons can be learned from these two countries' experiences, and can help others to go forward in the adoption and deployment of biotechnology in Africa.

Burkina Faso underwent a unique experience that can show that biotechnology can overcome challenges in legal frameworks, technocratic bureaucracy, and can be supported and sustained by business models that link the private sector to small-and medium-sized producers in developing countries. The surrounding countries such as Mali, Togo, Benin, and Ghana would probably benefit as much as Burkina Faso in Bt cotton technology and could be next in line in the introduction of the technology, once legal frameworks are established. The adoption of biotechnology was facilitated by not only the political will of the authorities of the country, but also by the efforts of all the stakeholders. Indeed, the country has benefited from the support of many players in moving biosafety forward. Among those inside and outside the country are the government, lawyers, universities, researchers, NGOs, national and international activists, the African Biosafety Network of Expertise—New Partnership for Africa's Development (ABNE–NEPAD), the West African Monetary and Economic Union (UEMOA), the Forum for Agricultural Research in Africa—Strengthening Capacity for Safe Biotechnology Management in Sub-Saharan Africa (FARA-SABIMA), West and Central African Council for Agricultural Research and Development (CORAF/WECARD), the Economic Community Of West African States (ECOWAS), African Agricultural Technology Foundation (AATF), and the International Service for the Acquisition of Agri-biotech Applications (ISAAA).

In the development process of Bt cotton, sensitization and communication were done by scientists, with great contributions from the Burkina Biotech Association

(BBA), and the West African Network of Communicators in Biotechnology (RECOAB). These two associations, with the financial support of ISAAA, were involved in advising and training policy and decision makers (Members of Parliaments), and journalists of Burkina Faso and other African countries. The President of the BBA, Professor Alassane Séré, was right in arguing that "If Africa missed the first green revolution, it should not miss that concerning the contribution of biotechnology to the development of agriculture, and we have to ask ourselves: Will Africa still run behind a new green revolution? (Séré 2007)"

The Bt genes have been transferred into the local landraces (FK 37, FK 290, STAM 59A), and adapted to the agro-ecological conditions of the country. The ownership is shared by farmers, INERA, Monsanto, and the cotton companies. Since 1999 and after the privatization in 2005, cotton producers have been shareholders of the three cotton companies. The cotton sector has since been jointly owned by the Burkina Faso Government, the private sector, and the farmers. So, all the stakeholders can benefit from any technology such as the Bt cotton recently adopted and commercialized.

But for sustainability, many efforts should be made by all the stakeholders in order to meet the future challenges and strengthen the cotton sector. To avoid challenges related to benefit sharing, there is a need to establish trust in both the public and private sector, as a means to secure the future of agbiotech public/private partnerships (PPPs) in the country through transparent interactions and clearly defined project priorities, roles and responsibilities among core partners (Obidimma et al. 2009; Obidimma and Abdallah 2012). There is also a need for improved communication strategies and appropriate media response, to obviate unwarranted public perceptions of the project. The country should continue building its capacity in terms of human resources and laboratory equipments, to respond adequately to the new challenges.

Studies should continue to take place on issues like the resistance of targeted pests to Bt toxins, and the environmental risks related to Bt cotton.

Scientists should continue training the extension staffs of the cotton companies as well as farmers on technical issues about cotton as a whole but particularly about Bt cotton. Farmers' associations still need support to be empowered in some issues such as communication, management, and negotiation. Farmers should also be sensitized, trained, and convinced about the implementation of refuge zones in their Bt cotton fields (20 % of the area planted). Continued monitoring will be required to determine the technical and economic viability of Bt cotton over the short and long term. Since cotton is part of a production system including cereals, studies should be undertaken on the development of a suitable farm council which will enhance the ability of the producer to make the diagnosis of his/her farm, in order to consider actions to improve incomes.

During this phase of deployment of the product, it is still critical to have an integrated communication and awareness training program for all players on the product life-cycle, including researchers, developers, cotton company extension workers, seed producers, farmers, and staff at the ginning facilities.

Stewardship awareness and training were essential thanks to the FARA-SABIMA project, not only for staff and stakeholders involved with early-stage research CFTs, but also all along the development chain through to farmers commercializing Bt cotton (Traoré and Héma 2011).

At this stage of commercialization of Bt cotton, it is important to prevent the mixing of GM and conventional seed. For example, during this process of conducting trials in farmers' fields when it became clear that INERA scientists were unable to personally oversee all plantings, monitoring, harvesting, and ginning activities for the cotton grown by the 20 farmers, it was decided that the solution was to adapt its approach to more fully engage its partners and other stakeholders along the entire value chain, and to serve as a training and facilitating organization.

We identified critical control points (CCPs), and developed standard operating procedures (SOPs) along the cotton production process from taking seed to farmers through to ginning, to ensure product integrity and prevent inadvertent mixing of seeds (Traoré and Héma 2011). Tracking of product and verification procedures are essential to reduce the risk of cross-contamination.

Efforts towards the intensification of production systems must continue to ensure better profitability, and INERA scientists have a great role to play by training farmers on the technical itinerary of production of Bt cotton, in collaboration with the cotton companies and Monsanto.

A challenge is about to be overcome, but other challenges including weeding, hunger, and malnutrition should be considered, since biotechnology can offer some solutions. Indeed, in Burkina Faso, hunger still remains in some regions, and every day, if one considers the number of Burkinabè who are going to sleep without eating, this serves as extra motivation to continue the effort. At INERA, the responsibility of the scientific community is to help farmers by providing them access to nutrition. Biotechnology can be used as a tool to increase productivity and to target malnutrition by improving food quality (biofortification). Research in biotechnology can target other issues such as biotic and abiotic stresses (resistance to insects and diseases, drought tolerance), and tissue culture. So, some biotechnology projects such as the African biofortified sorghum project, the Bt cowpea project, and the SABIMA-FARA project are in the pipeline with hopes of success. INERA is still in discussion with Monsanto for the evaluation of the Roundup Reddy Flex herbicide-tolerant cotton. Hopefully, the fight will continue to reduce poverty and help farmers achieve food security.

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